AMERICAN SOCIETY OF CIVIL ENGINEERS.
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326.
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THE SPONGILLA IN MAIN PIPES.

By DESMOND FITZGERALD, M. Am. Soc. C. E.

READ OCTOBER 15TH, 1884.

WITH DISCUSSION.

Great attention is paid by hydraulic engineers to the designing of dams, aqueducts, reservoirs, etc.—structures connected with the sources of supply; but the question may well be asked: Is proper attention given to the pipe or distribution system ?

Experiments and formulas we certainly have on the flow of water through pipes, but the writer is inclined to believe, as the result of observation, that when the water has been once turned into a pipe system, little more attention is paid to the condition of the pipes. Sometimes, it is true, small pipes fill up entirely, and then specimens are exhibited showing the growth of tuberculation. Again, the water becomes bad in one street while it is good in the adjoining neighborhood, and the

result is attributed to some mysterious agency. It is the belief of the writer that one of the great steps in advance that will be made in the years to come in the designing of pipe systems will be the introduction of facilities for cleaning out the pipes at stated intervals of time. This will be found necessary, not so much for the purpose of restoring the normal capacity of the pipes, as for maintaining the purity of the water.

A few years since, the writer was standing by the side of Prof. Remsen when he made the discovery of the *spongilla* as being the principal source of trouble in the Boston water.

Many excellent engineers have doubted the influence of the sponge, but in a somewhat varied experience in different sources since that time, the writer is inclined to give more and more weight to the conclusions of Prof. Remsen. Not to go into the question of the growth and development of the *spongilla* in lakes, reservoirs, etc., which may be made the subject of a future article, the writer would like to call the attention of the profession to the fact of the growth of the *spongilla lacustris* in the pipes of a water system. When the sponge is present in the sources of supply, pieces of it find their way into the pipes. These, decaying, give an offensive cucumber or fishy taste to the water. This accounts for the fact that the bad taste is almost always detected in the city a few days before the taste is found in the reservoirs. The sponge is really an animal and lays eggs, which float down with the water and attach themselves in large quantities to the interior surfaces of the pipes.

More accurately, these reticulated masses are the *statoblasts* of the sponge. The forms which these eggs take are very curious. They mass themselves in traceries like lace-work, generally from the size of a silver half-dollar to the size of a plate, and the exterior boundaries generally take a circular or oval form. Soon the eggs begin to bring forth the sponge, no matter what the pressure, and a soft velvety, light green sponge begins to grow in circular patches. This growth, if left undisturbed, gives out long fingers of sponge.

With life there must be death and decay, and with the decay of the sponge comes the cucumber taste.

The writer has seen large mains, under a pressure of 100 feet, where the entire surface, as far as examined, was filled with offensive masses of sponge closely packed between and around the tubercles. He has also seen them in all the stages of growth. Within a few days a break

in a 48-inch main gave an opportunity to examine the sponge in company with Prof. Hyatt, who recognized the young sponge as *spongilla lacustris*, var. *flexis pina*. Flushing will not remove this growth. Some form of scraper or wire brush is necessary. In Halifax, Mr. E. H. Keating, M. Am. Soc. C. E., has perfected and used extensively an apparatus for cleaning out pipes, but one of the difficulties of this form of scraper will probably be found to be the protrusion into the interior of the pipes of service-pipe connections, etc., which has been found to be necessary to keep rust from covering them. It would seem, however, that some form of brush might be devised which would do the work effectively.

DISCUSSION.

JOSEPH P. DAVIS, Vice-President Am. Soc. C. E.—The result of a good many experiments in Boston has been that, under the conditions which produce what is known as the cucumber taste, if the pipes are blown out the bad taste increases. The *spongilla* was discovered to be the cause of the cucumber taste some few years ago by Prof. Ira Remsen, of the Johns Hopkins University. There was a comparatively small amount of it in the pond where it was discovered; one could hardly believe such a small quantity could produce such a bad effect. The presence of a sponge-like growth in the Cochituate conduit was noticed soon after Cochituate water was introduced, but although in 1854 (I think that is the year) the cucumber taste rendered the water unfit for use, no one seems to have suspected that the taste arose from the *spongilla*.

E. B. DORSEY, M. Am. Soc. C. E.—Was that undoubtedly the cause of the bad water?

Mr. DAVIS.—There is, perhaps, some doubt about it. But we are inclined to believe that that was the cause. It is very curious how the presence of this taste is usually first made known. In 1876 it occurred something in this way. A consumer would come into the office and say the water supplied to his house was exceedingly bad. On asking him where he was now getting his water from, he would say, from his neighbor. "Was that good?" "Yes." Naturally we supposed a fish had got into his supply pipe. During the day, probably a number of persons would come in complaining of their water, whereas their

neighbor's water was good. In the next 24 hours the whole section would be troubled, and within two or three days it would be all over the city. In that year (1876) no bad taste was found in the reservoirs for two or three days after the discovery in the city. I do not know what the life of the animal is, but the effect produced upon the water by its decay lasts sometimes two or three months. The supply for Boston was (in 1876) brought to the city by a single aqueduct and delivered into two reservoirs, one of which, the Chestnut Hill reservoir, had two basins; the lower was quite a large one and as clean a one as I ever knew of. The first knowledge of any trouble in the city was had as I have described it. I was out some two or three days trying to find the source of the trouble, and found it in the lower basin of this reservoir. The supply was shut off for some three or four months, when it was again turned on. It did not seem possible there could have been any growth in the basin. Since that time Prof. Remsen has found this *spongilla* growing in the ponds.

J. J. R. Croes, M. Am. Soc. C. E.—In cases where this has grown in the pipes—the supply pipe—how long does it last? I suppose it has a growth and death, and decomposition comes on?

Mr. Davis.—The taste sometimes lasts for two or three weeks in the pipes. In the reservoir, where it was not carried away by the current, it lasted some two or three months in the winter.

Mr. Dorsey.—Does it recur at the same time of the year?

Mr. Davis.—I think not.

Theodore Cooper, M. Am. Soc. C. E.—Can you distinguish it with the eye?

Mr. Davis.—It attaches itself to the rocks and grows like sea-weed.

Mr. Dorsey.—Is it green?

Mr. Davis.—When fresh and alive.

J. C. Campbell, M. Am. Soc. C. E.—Has there ever been anything done to prevent it?

Mr. Davis.—When it first occurred a thorough blowing out of the pipes was made, but it resulted in an increase of the taste. Of late years, finding that this only made it worse, we did not do it.

Mr. Croes.—Has this ever occurred in a supply that is taken from water not exposed to light or air? If I am not mistaken it only occurs where the water is exposed to light and air.

Mr. Davis.—I don't think I ever heard of a case where the water was not exposed that it became bad from this cause.

Mr. Dorsey.—Have they ever tried the ordinary sand or gravel filter?

Mr. Davis.—In Boston? No, sir; not for the purpose of taking this taste out. Experiments have been made for other objects. Of course, it takes out little or nothing held in solution. When you get the taste you cannot filter it out. In the early days of the Cochituate supply, sponge filters on the house faucets were very generally used, but when the bad taste developed in 1854 they had no beneficial effect. Exposure of the water to the air for a short time, in small quantities, or boiling, usually destroys the taste.

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ON INCREASING THE ACCURACY OF A SYSTEM OF MAGNETIC BEARINGS OF A SURVEY.

By OLIN H. LANDRETH, M. Am. Soc. C. E.

READ NOVEMBER 14TH, 1884.

WITH DISCUSSION.

This system is applicable to a closed survey or to a traverse. It often becomes necessary to assign a set of magnetic bearings to a survey in which the horizontal angles have been measured with a transit or a theodolite. The required system of bearings must conform to two conditions:

First.—It must be the most accurate system attainable from the given data.

Second.—It must conform to the vernier system by giving angles between adjacent courses identical with the corresponding vernier angles.

These two imposed conditions are best satisfied by the following method of survey and reduction:

1st. Measure and record the traverse angle at each station referred to the first line of the survey as an origin.

2d. Observe and record the magnetic bearing of each line, taking as such bearing the average of the bearings taken at the two ends of the line.

3d. Apply the traverse angle, with its sign reversed at each station,

to the magnetic bearing of the line starting from that station, by so doing forming a series of bearings of the first or origin line, each transferred from a separate line of the survey.

4th. Take the arithmetical mean or average of the several values of the bearing of the first side as the adopted bearing of that side.

5th. Apply the traverse angles, with their true sign, in turn to the adopted bearing of the first side, giving, respectively, the corrected bearings of each side.

This last operation may be facilitated by inspection, remembering that the corrected bearing of each line differs from the observed bearing in amount and direction, the same as the adopted bearing of the first line differs from that computed bearing of the first line which comes from the line in question.

If traverse angles have not been measured, but deflection angles, construct the corresponding traverse angles for the several stations by adding all deflection angles to the right and subtracting from the sum all deflection angles to the left which occur between the first line and the line in question.

The magnetic bearings may now be transformed into astronomical bearings by applying the magnetic declination.

It will be observed that the final corrected bearing of each line is determined from the bearings of every line of the survey, and hence is more accurate, both as regards ordinary instrumental errors as well as the effect of local attraction, than the bearing from one or even many observations at each station.

The unknown effect of local attraction at the several stations of an extensive survey may be assumed to be free from any tendency to a common direction, and hence these effects can be treated as accidental errors, making the degree of accuracy proportional to the square root of the number of stations.

Should the observed bearings of the individual lines be deemed of unequal accuracy, relative weights may be assigned to them, based on the candid judgment of the surveyor, in which case each computed bearing of the origin side is to be multiplied by the weight of the observed bearing of the corresponding line, and the sum of these products for all the lines is to be divided by the sum of all the weights, to give the adopted mean value of the bearing of the origin side, or the general mean.

EXAMPLE.—CLOSED SURVEY.

STATION.	Deflection Angles.		Observed or Computed Traverse Angles.		Observed Bearings.	Computed Bearings of First Line F. A.	Corrected Bearings.
	Deg.	Min.	Deg.	Min.	Deg. Min.	Deg. Min.	Deg. Min.
					N. 46 30 W.	N. 46 30 W.	N. 46 32 W.
A.........	98	12	98	12			
					N. 51 45 E.	46 27	N. 51 40 E.
B.........	38	18	136	30			
					N. 90 00 E.	46 30	N. 89 58 E.
C.........	34	07	170	37			
					S. 56 00 E.	46 37	S. 55 55 E.
D.........	89	14	259	51			
					S. 33 15 W.	46 36	S. 33 19 W.
E.........	72	13	332	04			
					N. 74 30 W.	46 34	N. 74 28 W.
F.........	27	56	360	00			
					N. 46 30 W.		
						Aver'ge 46 32+	

DISCUSSION.

RUDOLPH HERING, M. Am. Soc. C. E.—Mr. Landreth's system is, I think, a good way of distributing the bearings over a closed survey; but unless this survey be small, and the territory free from local attractions, I cannot see that the magnetic bearings, particularly the corrected ones, could be of much use after a complete vernier circuit has been made. To correct the error of local attractions, and alter the magnetic bearing at any one point, would often be to mislead any one thereafter trying to retrace a course on the ground.

It is better, I think, to record the actual magnetic variation, even if the magnetic circuit does not close (and the date, inasmuch as it varies periodically), and not to try to average it for a whole circuit. On the survey I am at present conducting, the method proposed would be of no value, as we find numerous local attractions of great amount, owing to the geological character of the ground.

J. B. DAVIS, Jun. Am. Soc. C. E.—Mr. Landreth's method of assigning magnetic bearing to the courses of a survey, is the one I should certainly practice if there were no local attractions involved, if I had occasion to do such a thing. In my own experience I have never had such occasion; neither do I find myself able to conceive of such an occasion. We are discarding all needle work in Michigan as fast as possible. I need not say why. The least experience with the needle will furnish plenty of reasons.

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MEXICAN BRIDGE CONSTRUCTION.

By J. FOSTER FLAGG, M. Am. Soc. C. E.
READ DECEMBER 17TH, 1884.

The accompanying sketch is submitted as being rather remarkable for the work, from his own design, of an ordinary uneducated Mexican laborer, or *peon*—combining as it does, crudely, several principles of bridge construction.

Bridges in Mexico are, generally speaking, built of arched masonry, anything like a truss, especially in the section of country where this bridge was built (the State of Colima), being before the advent of railroads almost unknown. In the State of Colima there are but few bridges of any description—the streams being crossed, when possible, by the primitive method of fording—and these few are the usual arched structures. The River Armeria, crossed by the bridge sketched, is, for a long distance above and below the bridge site, too rapid (having an average slope for miles of one per cent.), and generally, even in the lowest stage of water, too deep to be fordable. And the size of the river in flood (then 800 feet wide and 25 feet deep in the channel), and the instability

of its stony bed, make it altogether too expensive a matter with the limited means of the country to build a permanent high bridge. It was attempted some thirty-six years ago, thirty miles farther down, where the current is much less rapid—a structure of the usual character (a series of brick arches of limited span) of probably 800 to 1 000 feet in length being then built; but a freshet, the following year, cleaned out the whole structure, except an arch or two at one end.

The *peon* referred to was occupied some four years ago as a ferryman, where the trail for cargo mules crosses the river, carrying across the mule packs, pack saddles, etc., in a "dug out." And if any animals could not be forced to swim the rapid current by pelting them from the banks, he stripped himself, and, seizing the bell mare or riding animal by the mane, swam beside her, and forced her across to lead the rest. About that time he happened to see a *Harper's Weekly* (probably sent to some one of our engineers) which had in it an illustration of a suspension bridge. This was a new light to him, and he revolved the matter over in his mind to see if he could not imitate the bridge in the materials at his command, viz.: the round sticks and vines cut from the forest, and small rough-hewn sticks of timber. As a result he put up a structure closely imitating the ordinary suspension bridge, the cables and suspenders being twisted from wild vines (*bejucos*), and the former passed over rude frames for towers, and anchored to huge boulders in the river banks. It was built without any nails or iron of any kind. It was, of course, a frail structure, but it served very well for foot passengers, and for carrying across, on wheelbarrows or the backs of *peons*, the cargo of the mules. The writer found it quite an assistance in passing backwards and forwards men and tools employed in building a railroad bridge at the same site.

But a heavy freshet occurred the same year the bridge was built and destroyed every vestige of it. Finding it profitable, the *peon* engineer decided to renew it; and this time he was not satisfied with copying another's design, but originated the one submitted with this paper. Like the first one, it was put together without nails or metal of any description—the suspension cable, as before, being made of wild vines twisted, and all joints tied together with lighter vines used when green, no manufactured ropes even being used.

The piers were made by driving light poles a short distance into the river bed, in the form of a square, tying them together with other poles,

PLATE XIV.
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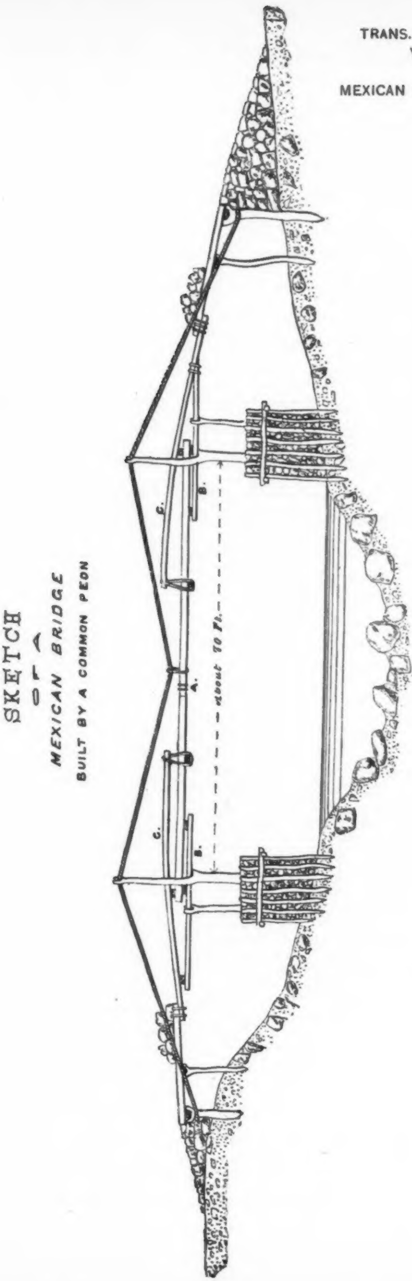
FLAGG ON
MEXICAN BRIDGE CONSTRUCTION.



and filling with stone. The stringers of the main span, in two pieces, were tied together with *bejucos* at A, and the spliced stick supported near the joint by the suspension cable—the only use to which the cable was put. The towers were natural forked sticks; forked to support the cable, and forked to support the corbels (B B) which assisted in shortening the main and lateral spans. And finally the long stringers were supported again, midway between the end of the corbels and the cable attachment in the center, by crude cantilevers (C C) which were loaded with stone near their shore ends to balance the weight of the central span.

The roadway, of rude joists and boards, is not shown. It was quite narrow, only one animal being able to pass on it at a time. The bridge proved to be strong and rigid enough to pass mounted men or loaded mules, and so served better than his first construction. It was in use, I believe without any accident, for some 18 months, when another heavy freshet unfortunately sent it the way of its predecessor.

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EXCAVATION AND EMBANKMENT BY WATER POWER.

By EDWARD BATES DORSEY, M. Am. Soc. C. E.
READ DECEMBER 17TH, 1884.

I wish to call the attention of the Society to a plan by which large excavations and embankments can be cheaply made—which is especially applicable to earthen dams—by simply applying the method used in the hydraulic mines that have been so largely developed in California. The system, in brief, is discharging the water under a vertical head of from 100 to 300 feet against the bank to be excavated. The momentum of the water cuts the bank, the material of which is conveyed by it into the flume, and thence by it to the place at which it is to be discharged.

This point of discharge is generally in some water-course or river, which soon becomes dammed by a perfectly water-tight dam, which remains intact and tight until it is destroyed, or partially so, by the winter's flood washing away the material from the top.

The water used in the mines is generally brought from reservoirs in the mountains. The dams forming these are brilliant examples of bold and cheap construction; among the principal of these is the Bowman Dam, on the headwaters of the Yuba River in Nevada County, California,

built under the general direction of Mr. Hamilton Smith, Jr., M. Am. Soc. C. E. Its maximum height is 100 feet, and length 425 feet.

The water from the reservoirs is conveyed through ditches, tunnels, flumes and pipes to the mines; in some cases aggregating a length of several hundred miles. These flumes show at times very bold engineering, being hung by iron rods to the vertical sides of the mountains; at other times they cross wide and deep valleys upon high and long trestle-work. When the valleys are too deep to be crossed in this manner, inverted siphons are used, made of wrought-iron sheets riveted into pipes. The great pressure these pipes stand, their lightness, durability and cheapness, will, in the future, force their adoption in many cases upon the hydraulic engineer. Some of these works, generally known as mining ditches, eclipse in magnitude and boldness the water-works supplying most of our or European large cities.

The unit of measurement of water in California is what is known as the miner's inch, which varies in different localities; the inch that is generally adopted equals 17 000 U. S. gallons in twenty-four hours.

The quantity of earth that this miner's inch will remove varies very much, being from 1½ to 9 cubic yards daily. Perhaps the most correct data is from the workings of the North Bloomfield Gravel Company, under the direction of Mr. Hamilton Smith, Jr.

During 1874–75, one inch of water removed 4.80 cubic yards gravel.
" 1875–76 " " " 4.17 " " "

In many cases the engineer in constructing dams could do better than this, as he could pick out the soft places and leave the hard, and not waste time and water in cleaning the bed rock or working the hard blue gravel which is generally richest in gold, and in mining operations must necessarily be mined and removed, even if it is done slowly.

In order to be perfectly safe, I have estimated that the miner's inch of 17 000 U. S. gallons daily will remove 3½ cubic yards. Upon this basis, actual bids were received for the construction of the plant, embracing engines, boilers, etc., to pump 20 000 000 gallons 200 feet high in twenty-fours hours.

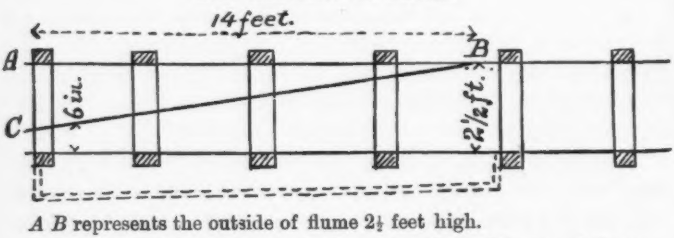
Recently I had to estimate the cost of constructing a dam 80 feet high. The surroundings prevented the use of masonry; the nearest material that would answer for puddle would have to be hauled four miles up a very steep grade; the only material available for building the

body of the dam was a sandy gravel extending to the greatest explored depth. By numerous tests the voids ranged from 8 to 23 per cent., averaging 10 per cent.

As the building material, as well as the foundation, was bad, I deemed it prudent to give the dam extra width; consequently the top was estimated 200 feet wide, with slope 2½ to 1 on each side, making the bottom 600 feet. One of the reasons for giving this great width was to get plenty of fine material for the interior filling that would take the place of the ordinary puddle. The calculated quantity of material was 1 757-127 cubic yards.

The plan proposed was to pump the water to an average height of 200 feet; of this, 120 feet would be available for hydraulic purposes, the remaining 80 feet would be lost in friction, fall of the flume, and dump. It was proposed to convey the water from the pumps to the banks by the usual hydraulic mining-pipe, made by riveting together sheets of wrought-iron. The water and the material would be conveyed to the proposed dam embankment in a flume 2.5 x 2.5 feet, made out of 1½-inch planks, with a fall varying from 5 per cent. at the beginning of the work to 2 at the close. This flume would be made similar to the ordinary mining flume, except that it would not be paved in the usual manner, either with stone or wooden blocks, but the bottom would be lined with thin sheets of steel plates, to prevent the wearing of the planks and to make the friction of the water and the conveyed material as small as possible. A few feet from the discharging end of the flume the upper portion of the side of the flume towards the center of the embankment would be cut away, commencing, say at a point 14 feet back where the height of the side would be 2½ feet, and diminishing to, say, 6 inches, at the end, thus:

SIDE ELEVATION OF FLUME.



A B represents the outside of flume 2½ feet high.

C B represents the side towards the center of the dam as cut away.

The dotted lines represent a trough or box to catch the overflow from *B C*.

By this plan, most of the water containing the lighter and finer materials only, would overflow into the trough represented by the dotted lines as above, and be conveyed by smaller branch flumes towards the center of the embankment, where it would be discharged and settle, forming a center of fine puddle; the stones, gravel and coarse sand would be on or near the bottom, below the side opening, consequently they would be discharged at the end, forming an excellent rip-rap for the embankment. This side opening could be raised or lowered as the material or work might require.

I will briefly describe the plan that I proposed to adopt in building this dam, using for example a dam 80 feet high and 200 feet wide on top, with slopes of 2½ horizontal to 1 vertical.

FIG. 1.

Fig. 1 represents the ground prepared for construction. *A* the usual puddle ditch, the material from which would be used to make *B* and *C*, small embankments, ten to fifteen feet high at the extreme base of the main embankment, this being to retain the muddy water until the finer particles held in suspension are deposited, so as to waste as little material as possible.

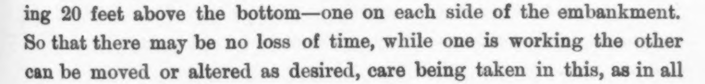


FIG. 2.

Fig. 2 represents the first hydraulic working, the flumes *F F* being 20 feet above the bottom—one on each side of the embankment. So that there may be no loss of time, while one is working the other can be moved or altered as desired, care being taken in this, as in all subsequent operations, to keep the outside or rip-rap portion of the wall closely built up to the discharging end of the flume. By doing this, a few planks, brush and stones can easily control and divert the water wherever desired.

The outer wall in this, as well as in all subsequent stages, should be kept as high as possible, in order to save the muddy water until the sediment in suspension is deposited.

FIG. 3.

Figure 3 represents the second hydraulic stage. In this the flumes *F F* are 40 feet above the bottom.

The upper part of the water in the flume, containing the finer materials, escapes over the low side opening into the trough and branch flumes *H H*, and is discharged over the puddle pit.

In this case it was estimated that one-fourth of the total quantity would be deposited here, and would make a most excellent puddling material. However, this proportion could be easily varied by raising or lowering the side discharge, as may be found desirable, to make the puddle finer or coarser.

On the figures the puddling material is represented by the broken horizontal lines, which also indicate approximately the form it would assume from the deposits made during the different stages.

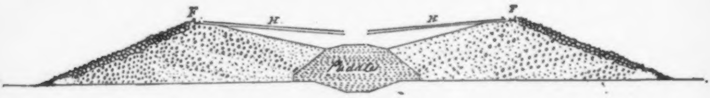


FIG. 4.

Figure 4 represents the third hydraulic stage, the flume being 60 feet above the bottom of the embankment.

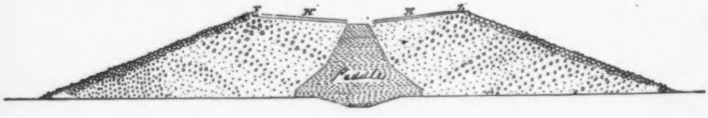


FIG. 5.

Figure 5 represents the fourth or last hydraulic stage.

In this case there was not enough water running in the stream to give an average of 20 000 000 gallons daily. It was proposed to keep the

water between the two embankments as long as possible, then to allow it to escape into the reservoir being formed by the dam, where it would deposit on the sides and bottom (which might be very desirable in some formations) the remaining sediment in suspension; after this it could be pumped again against the bank. By thus using the same water over repeatedly, very little fresh water would be required.

Cost.

The following table is taken from the able paper on "Hydraulic Mining in California," by Aug. J. Bowie, M. Am. Soc. C. E.*

Name of Mine.	Year.	Cost per Cubic Yard Moved.		
		Water.	Total.	Total except Water.
French Hill Claim	1874-76	$0.014	$0.063	$0.049
Light Claim	1875-76	.006	.038	.032
Chesnan Claim	1874-76	.008	.055	.047
Johnson Claim	1875	.006	.037	.031
Sicard Claim	1874-75	.004	.039	.035
North Bloomfield Gravel Mining Company	1874-75	.0077	.0207	.0130
Ditto ditto	1875-76	.0074	.0245	.0171

The two last were made under the superintendence of Mr. Hamilton Smith, Jr., M. Am. Soc. C. E., in his usual thorough manner, and give the correct cost, under favorable circumstances of high banks, plenty of water, good grade, and first-class management.

The engineer in any ordinary work could not expect to equal this work of Mr. Smith; but he would, in my judgment, except under very unfavorable circumstances, be perfectly safe in estimating at four cents per cubic yard the cost of digging, transporting, depositing the material in embankment, and all other expenses, except that of water and plant.

The preceding statement of expenses at the mines included many items of expense not necessary in ordinary engineering work, such as

* Hydraulic Mining in California. By Aug. J. Bowie. Transactions of the American Institute of Mining Engineers, Vol. VI, page 27.

loss of quicksilver, loss of labor and water in cleaning bed rock; watchmen to prevent robbery of gold; expenses of saving the gold; expenses of cleaning up, etc.

Cost of Plant.

A plant capable of pumping 20 000 000 gallons of water 200 feet high daily, which should remove 4 117 cubic yards of average earth or gravel, will cost, all complete and in working order, about $50 000, unless the local freight should be excessive. This is made from actual bids.

In this latitude this system could be worked all the year, except during the severe winter months, say for 200 days, in which time it would remove $4\,117 \times 200 = 823\,400$ cubic yards, so that the cost of the plant would be as follows per cubic yard removed. In work lasting

One year	$0.06
Two years	0.03
Three years	0.02
Four years	0.015

In this estimate nothing is allowed for the value of the plant at the end of the work. The engine, boilers, pumps, tools, electric lights, etc., would certainly bring something, which would reduce it materially.

In warmer climates, where the work could be prosecuted all the year, the above estimate would be largely reduced.

Cost of Water.

Wherever this system could be used in ordinary engineering work, the time that would be required would generally be too short to justify the purchase of compound or condensing engines, consequently the cost of pumping is calculated on the ordinary high-pressure engine consuming 36 tons of coal to pump 20 000 000 gallons daily 200 feet high:

36 tons of coal, at $4.50	$162.00
1 engineer	4.00
2 assistant engineers	6.00
2 firemen	4.00
4 laborers	6.00
Oil, waste, etc.	8.00
Total	$190.00

\$190 ÷ 4 117: \$.046. Average cost per cubic yard, say \$0.045.

This estimate is based upon the supposition of pumping all the water 200 feet high, but in most localities a few cheap dams and ditches could be made to bring considerable water at an elevation that would materially reduce this pumping expense.

RESUMÉ OF COST PER CUBIC YARD.

	DURATION OF WORK.					
	1 Year.	2 Years.	3 Years.	4 Years.	5 Years.	6 Years.
Water	\$0.045	\$0.045	\$0.045	\$0.045	\$0.045	\$0.045
Plant	.06	.03	.02	.015	.012	.01
All other expenses	.04	.04	.04	.04	.04	.04
Total	\$0.145	\$0.115	\$0.105	\$0.100	\$0.097	\$0.095

In my opinion this plan will often enable the engineer to build cheap and safe dams where it would be impossible to build, at any reasonable cost, masonry or earth dams.

It could be used for excavating and removing all classes of earth or soil, except compact pipe clay. For constructing or building up embankments, it cannot be advantageously used where the earth for constructing the proposed work contains a great quantity of loam or clay; for this purpose the earth should contain a fair percentage of gravel and sand.

The cheapness with which the material can be moved by this system enables the engineer to use a much greater quantity than he would think of doing with the usual expensive systems.

Based upon my experience, I think a safe dam can be made of sand or on a sandy foundation, provided sufficient thickness is given to it, so that the head of the water will be neutralized by its friction in passing through the sand. This dam will undoubtedly leak, but probably not as much as required for compensation to the riparian owners on the stream below. This leakage will diminish with time, owing to the deposit of sediment on the bottom and sides of the reservoir. This deposit could be accelerated to any desired extent in the proposed plan by running the muddy water from the flume into the reservoir.

Wherever this plan can be adopted, it should commend itself to the engineer for several reasons :

First.—It will be much cheaper than the earth dam constructed in the usual manner—at least one-half where the material is good; and where the material is bad, the difference would be still greater, probably one-fourth.

Second.—It will permit the construction of earth dams where the material is so bad that the ordinary dam could not be constructed.

Third.—Owing to the cheapness, the dam could be made much stronger.

Fourth.—The dam will not settle or crack. It is as compact and as solid at the beginning as it can be made.

Fifth.—As it will not settle or crack, it is ready for use as soon as it is finished.

In the proposed plan, there is nothing new, except that the working head of 120 feet is derived from pumping machinery instead of gravity. This makes no difference in the result, except in increasing the cost. The prices of plant named in this paper are actual bids from manufacturers, with a guarantee not to burn more coal than estimated. In every other respect the plan is identical with that which has moved millions of tons in California, at a cost impossible by any other method.

DISCUSSION.

WILLIAM R. HUTTON, M. Am. Soc. C. E.—In the construction of the reservoir of Lac d'Oredon, in the Pyrenees (France), among other uses of water, the embankment was put in place by its means. A wooden box about 6 x 9 inches, with an inclination of 0.5 per 100, was placed alongside the railroad upon which the material was brought, and was extended as the work progressed. Two, sometimes three car-loads of earth (4.5 to 6.5 cubic yards) were dumped over the end of the box, and a current of water (about ½ a cubic foot) was turned into it. The saturated earth was carried forward by the current, and down to the base of the embankment. Four or five men with hooks guided the large blocks of stone towards the faces of the bank. After reaching the bottom of the bank, the water flowed off, carrying only a little humus and some very fine sand. After a few minutes the material settled away from the water, and became very solid. Every space between the stones was compactly filled with sand, making a perfectly solid bank.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

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330.

(Vol. XV.—May, 1886.)

PERMANENT TRANSMITTING DYNAMOMETER.

By CHARLES A. SMITH, M. Am. Soc. C. E.

READ MAY 21ST, 1884.

In the fall of 1879, during the construction of the machine and engine-room of the Manual Training School at St. Louis, the author suggested that a permanent transmitting dynamometer should be made in connection with the use of the plant for experimental purposes, and the machine of which a rough sketch is given, was built.

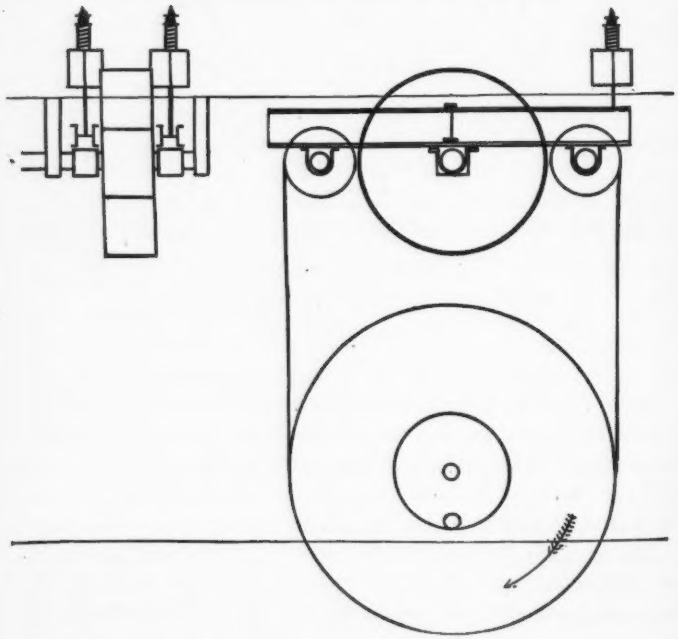
The type selected was one first used by Horatio Allen, Hon. M. Am. Soc. C. E., in the experiments with steam engines at the Novelty Iron-works, but with such modifications as seemed desirable. As it is now entering the seventh year of almost daily service, it is considered as having established itself.

The driving shaft of the engine is set vertically below the main line shaft of the building, and carries a driving pulley larger than that on the line shaft.

On each side of the driven pulley are two journals carrying a pair of balance beams which project beyond the driven pulley, and by means of journal and boxes carry two loose pulleys, one at each end.

These loose pulleys are so set that the belt from the driving wheel passes vertically to and from it under the driving and driven wheels, and over the loose pulleys.

The difference between the tension of the belt on the driving and driven sides is thus carried to the balance beams, which are kept from moving by a yoke attached to a spring resting on the floor above. The compression of this spring is used to measure the tension of the belt either directly or by the aid of a main integrating wheel and counter.



This form, with balance beam, is readily applied for permanent or temporary use. In the latter case, sheaves for rope would be advisable, as taking less room along the driven shaft, and the balance beams and driven pulley can easily be made of the width usually taken by a belt pulley.

The theory of the machine is so easily seen that it will not be intruded here. By taking the constants, in a convenient manner, the results are easily made very simple.

The vibration is about that of a friction brake, and is easily controlled.

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331.
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DATA FOR FLATTENING THE ENDS OF RAILROAD CURVES.

By ALBON P. MAN, Jr., M. Am. Soc. C. E.
READ NOVEMBER 19TH, 1884.

WITH DISCUSSION.

Assuming a curve uniform, except the flattened ends, as most scientific and convenient under ordinary circumstances, and that this flattening is only for the purpose of attaining proper elevation without intermediate improper elevation, throw of trains, etc., etc., the following is suggested:

1. That the ordinary rules for flattening curves are too seldom used, either because unsuited to the most important places, or requiring too much calculation or work. Rankine's rules give two different shifts to the same curve if the change at either end is not alike, as when to tangent at one end and reverse or compound at other, introducing thus a new complication.

2. That "Froude's curve" of deflections, as the cube of distances (or radii inversely proportionate to distance), applied to a curve shifted towards its center, is reasonably proper, suitable and convenient.

3. Since the uniform length of curve of adjustment here given is

200 feet (*i. e.*, 100 feet either side of *P. C.*, *P. C. C.*, or *P. R. C.**), it is assumed that all curves and tangents are at least 200 feet long, and that tangents of at least that length are left between reversed curvature (especially where the degree of curvature of the two curves added together exceeds 8 degrees), and this is always practicable, since an analysis of any alignment will show that such a tangent can always be attained by but a slight and unimportant variation in the line.

4. Although the data herewith perhaps give more than necessary length of flattening for light curves, yet the invariable length of 200 feet is chosen, upon the basis that what is suited to 6 or 8 degree curves at high speed will satisfy sharper curves, since speed is in practice reduced on such, and that what is practicable for sharp curves in the adjustment of location, will be easily attainable on light curves without material expense.

5. These curves are deemed adequate for a speed of say 40 miles per hour on 6 or 8 degree curves, and 60 miles on 3 or 4 degree curves; but it is hardly necessary to so flatten curves of more than a mile radius, or curves in yards or other places where trains are necessarily slow. The careful adjustment of these curve ends is considered as of most importance on trestles, bridges, or where the track is not easily readjusted after once fixed.

Explanations and Directions.

1. Shift all curves throughout their length radially towards their centers, each its degree of curvature multiplied by 0.2909 of a foot, as shown near bottom of Table I. These curves can be laid out, using the same deflections as for original curves, but a chain shortened from the usual hundred feet as shown immediately beneath the shift in same table. In such case, to save errors on account of difference of chaining, it is advisable to shift all the points, and chain the curves towards the instrument.

2. Lay off 100 feet along shifted line (or tangent) each way from original *P. C.*, *P. C. C.*, or *P. R. C.*, as the case may be, for limits of the curve of adjustment.

3. From tangent, or (if compound or reversed curve) from either shift curve produced, lay off deflections, and at distances as shown in table, taking, however (if both curves have been shifted), for compound

* *P. C.*, point of commencement, or end of curve; *P. C. C.*, point of change of, or compound curve; *P. R. C.*, point of reverse curve.

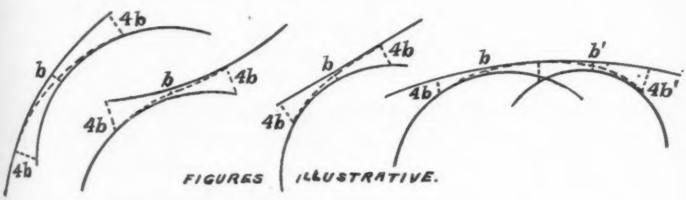
curve the column showing difference of degree of two curves, and for reversed curve the column showing the sum of degree of the two curves. If preferred, half the adjustment curve may be laid off from one end and half from the other, using only the first half of the column.

4. In case of other curve than shown in the table, multiply the column for 1 degree curve by the degree (and fraction) of the desired curve.

5. Centers can be put in 10, 20, 40 or 50 feet apart as deemed sufficient, or at intermediate distances on trestles, bridges, etc., wherever necessary, by interpolation in the table.

6. A table of ordinates 5 feet apart is added for more correctly and conveniently setting out uniform curves from their hundred-foot chords.

7. Proper elevation for speed of 38 miles per hour is the middle ordinate of 60 feet of rail on any curve = .078 of a foot per degree, or $\frac{94}{100}$ of an inch.



FIGURES ILLUSTRATIVE.

TABLE No. 1.—DISTANCES AND DEFLECTIONS, ETC., FOR FLATTENING CURVES—IN FEET AND DECIMALS.

DISTANCES.	Curve 1 degree.	2 degrees.	3 degrees.	4 degrees.	5 degrees.	6 degrees.	7 degrees.	8 degrees.	9 degrees.	10 degrees.	11 degrees.	12 degrees.
10	.0001545	.000	.000	.001	.001	.001	.001	.001	.001	.002	.002	.002
20	.0011634	.002	.003	.005	.006	.007	.008	.009	.010	.012	.013	.014
30	.00393	.008	012	.016	.020	.024	.028	.031	.035	.039	.043	.047
40	.00931	.019	.028	.037	.047	.056	.065	.074	.084	.098	102	.112
50	.01818	.036	.055	.073	.090	.110	.127	.145	.164	.182	.200	.218
60	.03141	.063	.094	.126	.157	.188	.220	.250	.283	.314	.346	.377
70	.04989	.100	.150	.200	.250	.300	.350	.400	.450	.500	.550	.600
80	07446	.150	.223	.298	.372	.447	.520	.596	.670	.745	.820	.894
90	.10603	.212	.318	.424	.530	.636	.742	.848	.954	1.060	1.166	1.272
100	.14544	.290	.436	.582	.727	.873	1.018	1.164	1.310	1.454	1.600	1.745
110	.19358	.387	.580	.774	.968	1.160	1 355	1.550	1.742	1.936	2.130	2.323
120	.25132	.503	.754	1.005	1.257	1.508	1.760	2.010	2.262	2.513	2.765	3 016
130	.31953	.640	.960	1.278	1.598	1 917	2 237	2.556	2.876	3.195	3.515	3.834
140	.39909	.798	1.197	1.596	1.995	2.395	2.794	3.193	3.592	3.990	4.390	4.790
150	.49086	.982	1.473	1.963	2.454	2.945	3.436	3.927	4.418	4 910	5.400	5.890
160	.59573	1.190	1.787	2.383	2.980	3.574	4.170	4.766	5.362	5.957	6.553	7.150
170	.71455	1.430	2.144	2.858	3.573	4.287	5.002	5.716	6.430	7.146	7.860	8.575
180	.84821	1.696	2.545	3.393	4.240	5.090	5.937	6.786	7.634	8.482	9.330	10.18
190	.99758	1.995	2.993	3.990	4.988	5.985	6.983	7.980	8.978	9.976	10.97	11.97
200	1.1635	2.327	3.490	4.654	5.818	6.980	8.145	9.308	10.47	11.64	12.80	13 96
Shift curve....	0.2909	0.58	0.87	1.16	1.45	1.75	2.04	2.33	2.62	2.91	3.20	3.49
Shorten chain..	0.005	0.020	0.046	0.08	0.13	0.18	0.25	0.32	0.41	0.51	0.61	0.73

TABLE No. 2.—ORDINATES OF UNIFORM CURVES—IN FEET AND DECIMALS.

DISTANCES.	Curve 1 degree.	2 degrees.	3 degrees.	4 degrees.	5 degrees.	6 degrees.
5	.0414	.083	.124	.166	.207	.249
10	.0785	.157	.236	.314	.393	.470
15	.1112	.222	.334	.445	.556	.667
20	.1396	.280	.420	.558	.698	.838
25	.1636	.327	.490	.655	.818	.980
30	.1832	.366	.550	.733	.916	1.100
35	.1985	.397	.596	.794	.943	1.190
40	.2094	.420	.628	.838	1.047	1.256
45	.2160	.432	.648	.864	1.080	1.296
50	.2182	.436	.655	.873	1.090	1.310

DISTANCES.	7 degrees.	8 degrees.	9 degrees.	10 degrees.	11 degrees.	12 degrees.
5	.290	.332	.373	.415	.456	.497
10	.550	.628	.707	.785	.864	.942
15	.780	.890	1.000	1.112	1.224	1.335
20	.977	1.117	1.256	1.396	1.536	1.675
25	1.145	1.310	1.473	1.636	1.800	1.964
30	1.293	1.466	1.650	1.832	2.016	2.200
35	1.390	1.588	1.787	1.985	2.184	2.382
40	1.466	1.675	1.885	2.094	2.303	2.513
45	1.512	1.728	1.944	2.160	2.376	2.592
50	1.527	1.746	1.964	2.182	2.400	2.618

FORMULAS AND EXCEPTIONAL CASES.

For speed of 40 miles per hour, length of adjustment curve is equal to 25 to 30 times degree of curvature (sum of degrees if reversed curve, difference if compound)—or in letters, $a = 25\ c$ (or $c + c^1$, or $c - c^1$)..(1)

Take it, however, as a convenient even number, then the shift for each curve will be 8 times the square of length of adjustment curve, multiplied by degree of curvature, divided by

$$1\ 100\ 000;\ \text{or}\ s = \frac{8\ a^2\ C}{1\ 100\ 000} \quad \text{(2)}$$

The deflection distance (d) of adjustment curve at any point distant x from the end of adjustment curve will be

$$(d) = \frac{4\ x^3}{a^3}\ s\ (\text{or}\ s \pm s^1) \quad \text{(3)}$$

To connect with an adjustment curve, detached curves, or curve and straight line detached, first shift the curve or curves, according to the table, or otherwise, if occasion require, by formulas, so as to allow of flattening other ends. Mark point where two lines are parallel—found half way between points where the two lines are equi-distant from each other. Measure the distance (b) between lines at the parallel point.

The ends of adjustment curve will come where the two lines are $4b$ apart, and in this case the length of it (a) must be taken as it comes, and not evened as above; or its length can be calculated if points distant (l) from each other have already been found where lines are equi-distant (e)—then $a = l\sqrt{\frac{3b}{e-b}}$ ....(1 a)

The deflection (d) at any distance (x) is found from $d = \frac{4bx^3}{a^3}$. .(3 a)

This last-above method will apply when curves in reverse direction have less than 200 feet of straight line connecting.

In case of curves in same direction—intersecting if produced, and not admitting of connection, by 200 feet or more of tangent—connect them by 200 feet or more of lighter curve than either, then shift all three curves and proceed by table.*

DISCUSSION.

W. Howard White, M. Am. Soc. C. E.—A very simple and satisfactory way of easing the ends of curves, which may be novel to many Members, consists in shifting the whole curve a uniform distance towards its center—that is, reducing its radius—after the road-bed is ready for the track. This has the effect of prolonging the curve at each end, and at the same time of easing the curvature in the end stations of the original curve.

Thus for a 5-degree curve, if we set the whole curve over ½ foot to the inside, and reduce this 25 per cent. at the original tangent points, the latter will have 0.38 foot deflection from the tangents. Now, if the tangent points are assumed as 100 feet from the old ones back on the tangents, the curve will begin with a 26-minute curve for one station. The 26 minutes deflected in this station is, of course, taken out of the 5 degrees, which would otherwise have been turned in the next 100 feet, making the angle in the same 4 degrees 34 minutes. The third station has the regular deflection of 5 degrees (all angles referred to are center angles).

The advantages of this method are three-fold. In the first place, it

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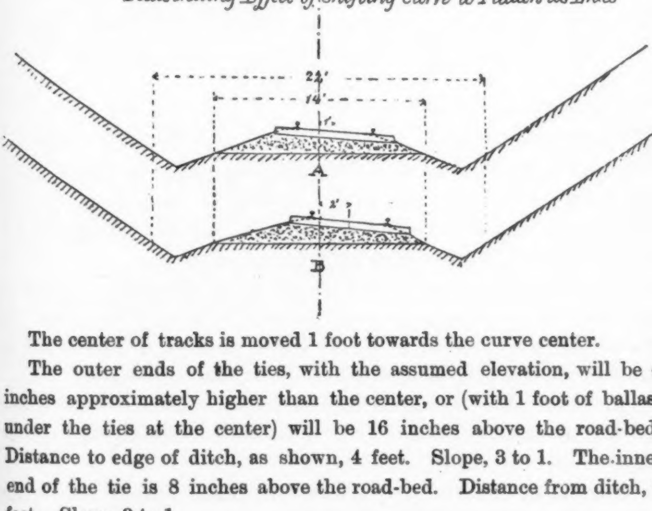
* The above formulas, etc., are partly adapted from Rankine.

avoids the extra work of putting in a compound curve instead of a simple one on given tangents. Secondly, it avoids compounding the curvature of the located line, and makes it much easier to mark the line permanently by monuments and to recover it, if a dispute arises as to right-of-way boundaries. Thirdly, the track lies better in the cuts and fills for maintenance when thus decentered.

I might add that it is also a method perfectly applicable to easing curves on completed lines where this point has not been looked out for in the construction.

The correctness of the third point of advantage gained will be seen on reference to the following figure. In *A* the track is represented shifted as here recommended, and elevated 0.04 feet per degree for a 10-degree curve.

Illustrating Effect of Shifting Curve to Flatten its Ends



The center of tracks is moved 1 foot towards the curve center.

The outer ends of the ties, with the assumed elevation, will be 4 inches approximately higher than the center, or (with 1 foot of ballast under the ties at the center) will be 16 inches above the road-bed. Distance to edge of ditch, as shown, 4 feet. Slope, 3 to 1. The inner end of the tie is 8 inches above the road-bed. Distance from ditch, 2 feet. Slope, 3 to 1.

So, while easing curve, we equalize ballast slopes in cuts, and it will be readily seen that the same applies on fills equally.

Of course with stone ballast this does not apply equally, but still it is of some advantage to have more room outside of the tie even with stone ballast, and the other advantages remain the same.

As to the amount of the above shifting, it will be perceived that the

basis for it in the examples given is 1½ times the difference of elevation of the two ends of the tie, or about 2½ times the super-elevation of the outer rail.

This proportion would be determined exactly by the width of road-bed, depth of ballast, and super-elevation used, if one wished to maintain a symmetrical section of the form I have shown at *A*.

I prefer, however, to use about double this—giving as follows:

	1° Curve.	5° Curve.	10° Curve.
Shift of tracks...........	0.20 feet	1.00 feet	2.00 feet
Offset of tangent point...	0.15 "	0.75 "	1.50 "
Angle in first station	0°10′	0°51′	1°42′
" " second "	0°50′	4° 9′	8°18′
" " third "	1°	5°	10°

I have shown at *B* the effect of this shifting for a 10-degree curve with the same elevation as before. It reduces the inner ballast slope to 1½ to 1 with the given road-bed, and if the outer be carried up 3 inches on the tie it will be a little flatter than 3 to 1.

The increased amount of shifting is desirable in order to give the entrance curve a more uniform increase of curvature, and its effect on the ballast appears to me not undesirable, since the outer slope should be flatter on account of its greater liability to wash—from carrying more drainage—and because it is on that side that stability against side thrust and vertical pressure of the train is needed.

The curvature in the second station of my tabulated examples is not uniform. The angle given is the total turned in the station. In reality the second station of the 10-degree example is made up of 35 feet of approximately 5-degree curve, and 65 feet of 10 degree.

In curves above 7 degrees it is desirable to carry the easing still further, by slightly offsetting the first station on the tangent. Curves eased in this way ride remarkably well.

The idea of easing a curve by offsetting had occurred to me before I knew of its being practiced elsewhere, and I first applied it by offsetting the whole construction, having the curved stakes moved over before the slopes were staked out.

The advantage of doing it on the completed road-bed was first pointed out to me by a letter on the subject to the *Railroad Gazette*, some years ago, from a gentleman whose name I unfortunately do not remember.

This method is particularly applicable to the relief of reversed curves.

Any superintendent who has one of these railroad racks on his division, who will take the trouble to have the whole of each of the curves moved inward and the track well lined between, will probably be astonished at the improvement.

A. M. WELLINGTON, M. Am. Soc. C. E.—In the *Railroad Gazette* of March 11th, 1881, I published a method for putting in transition or connecting curves by offsets, which gives in substance the same curve as that proposed by Mr. Man and Mr. White, viz.: a cubic parabola, but in which the method used was somewhat different, and, I think, preferable, requiring no shifting of the circular curve after it was once run, but running it in, in the beginning, at an offset from the tangent, after doing which a few stakes only, near the *P. C.*, need to be set over to complete the transition curve.

This method, however, like that of Mr. Man's and all others with which I am familiar, was incomplete in this : that it required a certain fixed offset for each curve. This is sometimes difficult to secure unless the offset is (as I think is the case with Mr. Man's method) made objectionably small; in addition to which, by expanding the method, so that transition curves of any length and offset may be used with any curve, we gain the great advantage that nice adjustment of the line to the topography of the country is greatly facilitated, and much time save din connecting new and old lines together when revisions have been introduced.

I therefore devised, while in Mexico, a method, which was extensively used on the lines under my charge in that country, for using any transition curve which the topography or other cause made most convenient with any curve. I consider this the preferable system by far for using such curves, since, so far from adding to the difficulties of the field-work of location, it so materially reduces them that it is easier to use transition curves than not to use them, while it enables us to use, wherever circumstances permit, long and easy transition curves, without impeding the use of shorter and quicker curves when necessary. I regret that it is out of my power to include a more formal description of this method in this discussion, but I hope to lay it before the Society at no distant day, contenting myself in the meantime with objecting to any method which requires always a fixed offset as inadequate to the requirements and unnecessarily limited.

Neither do I consider that the real reasons for invariably using such curves are always correctly put. An incidental advantage of them is that it enables the elevation of the outer rail to be always in correct ratio (or, at least, in uniform ratio) to the radius of the curve at each point, while passing from the tangent to the curve, and *vice versa;* but this gain, while undoubted, is only incidental and of minor importance. The chief purpose of such curves is (1) to avoid the shock incident to the almost instantaneous turning of the truck upon the center-pin, and especially the sudden jerk to the wheel-base of the locomotive; and (2) to avoid the sudden generation of great centrifugal force, with its attendant lateral jerk, and permit this force to be generated and applied gradually. For both of these latter purposes the curve can never be too long; and, therefore, should not be unnecessarily shortened in one place by any procrustean rule, because it may be essential to do so in another place. As a general rule economy of construction is materially promoted by the use of easy transition curves, for the reason that they are apt to more correctly fit the natural contour in swinging around a curve or a hollow.

My attention was drawn to this subject many years ago, by observing how absolutely invariable a rule it is, on old track in good condition, to find that the trackmen have extended the curve, as the engineer left it, back on to the tangents, usually for two or three hundred feet, by throwing the line inward at the tangent point, thus necessarily sharpening the curve somewhat at some point beyond the tangent point, but accomplishing the far more important end of easing the approach. This has been found essential by all trackmen to obtain easy riding track, and on hundreds of old curves whose existing alignment I have determined I have never found it absent. The same phenomenon has been observed by many other engineers on other roads, and accordingly it is among the engineers of lines in operation that we find the greatest efforts made to introduce such curves, while engineers who have been engaged chiefly or wholly on construction are apt to regard them as a rather pedantic refinement. I shall endeavor to avail myself of an early opportunity to lay the method I have referred to before the Society.

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332.
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ON CRANES AS LABOR-SAVING MACHINES.

By C. J. APPLEBY, M. Inst. C. E.
READ OCTOBER 17TH, 1883.

WITH DISCUSSION.

As a well-constructed crane, or other similar power machine requiring one man to drive it, will not only do as much work as can be done by ten men performing similar work by manual power, but in one-tenth of the time they would require, it seems singular that railroad and waterside depots should so rarely be laid out with a view to the immediate or ultimate employment of labor-saving machines of this kind. The result of this is, that when the pressure of increasing traffic comes, as it nearly always does, expedients have to be resorted to and expense incurred, both of which might have been avoided if proper provision had been made in the first instance.

These remarks apply with equal force to workshops, and to many works of construction, where the time and cost of handling materials is always a most important element.

Using the word "crane" as a short and convenient term for almost any kind of lifting machinery which may be generally used under the conditions above referred to, the considerations which seem to present themselves are:

First.—As to the best mode of applying or transmitting power; and

Second.—Whether machinery of this kind should be fixed, or, as far as possible, portable.

It may be well here to call attention to the self-evident fact, that the most economical working result is obtained from machines which are so arranged that when they take hold of the load it is not released until it has been deposited where it is required--such as from ship to car, or the reverse; from car to van for distribution; or, in workshops, from the machine to the erecting floor, and so on.

The question of transmission of power has been referred to in some papers read before the Institution of Civil Engineers (England), and in the Transactions of some of the technical societies on the Continent of Europe, but, so far as the writer knows, the subject has never been exhaustively treated, although those who have been engaged in crane construction possess a considerable amount of information as to the conditions under which the different systems can be most economically employed.

The systems of transmitting or applying power are:

1. The well known hydraulic system, with pressure pumps, accumulator and distributing pipes.

2. Compressed air distributed through pipes.

3. Steam, distributed as above.

4. High-speed rope, or "endless cotton cord," which runs at a speed of 5 000 to 6 000 feet per minute.

5. Low-speed rope, running 1 500 to 2 000 feet per minute.

6. Square shaft supported on tumbler bearings.

7. Steam from a boiler delivered on the top of a piston, with multiplying chains similar to the hydraulic system.

8. Boiler and engine fixed on the crane, and driving gear for the several motions required.

A consideration of these systems will lead to the conclusion that those numbered 1, 2 and 3 can only be applied to fixed cranes, or to such as have to be moved over a very limited area.

It will be evident that the arrangements enumerated under Nos. 4, 5 and 6 will transmit power over a very large area, but it should be rectangular, or nearly so; hence the use of this system has been limited to working overhead traveling cranes, driving capstans, and a few other and similar purposes.

The only system which can be used universally, wherever there is a railway track, is that referred to under No. 8.

The hydraulic system possesses indisputable advantages over compressed air or steam, and, although there are some drawbacks, it has been so extensively and successfully used, that the objections againstit go for very little when considerations of climate need not be taken into account. Experience in countries where the cold is far less severe than it is in the busy parts of this continent, points to the conclusion that the common use of hydraulic power will be attended with considerable inconvenience when winter begins to set in.

Compressed air has been used under very widely differing conditions, but it is considered by many to be a somewhat expensive mode of transmitting power. There seems no reason why it should be much more costly than hydraulic power, but, as a matter of fact, its use has been abandoned in many cases.

Steam is rather largely used for working warehouse hoists, capstans, cranes, etc., and it is common to carry it through 1 000 feet of pipe without further inconvenience than that incidental to the heat radiated from the pipes, and to the slight condensation which is inevitable, however well the pipes may be protected.

The high-speed cotton cord, as introduced and so successfully used by Mr. Ramsbottom, runs at a speed of 5 000 to 6 000 feet per minute. As is well known, the cord works in V-grooved pulleys, very accurately turned and balanced, the power being transmitted from one end of a building or shop. The cord is carried on rollers, or other supports, at intervals of 10 to 25 feet, passes over grooved pulleys on the machine to be driven, and finally over another grooved pulley, which is weighted so as to keep the cord in tension, and thus give the power required for working. The cost of the cotton cord is often considered a serious item; but probably the wear and tear complained of is due far more to negligence in fixing the supports, or to maintaining these high-speed bearings, than to any defect inherent in the design. In some cases the different motions are taken from the cord, which, in that case, takes the place of the shaft, as shown in Plate No. XV. But the writer believes the latter is better construction, and but little more costly. It will be understood that all cranes of this type are worked by one man, whether they be 5 or 50 tons power.

Low-speed rope transmission differs from that last described only in

the speed of the rope, which is 1 500 to 2 000 feet per minute. Any good hemp rope, usually 1 inch to 1¼ inches diameter, answers every purpose, and if fairly well looked after will last a long time; but it is desirable to change the ropes at intervals of one to two years. The speed is sufficient to give the necessary driving power, but evidently the tightening gear must be heavier and stronger than that required for the higher speed rope or cord.

The square shaft (Plates Nos. XVI and XVII) has been used for many years, but to a less extent than it might have been, owing to the difficulty experienced in properly supporting the long line of main driving shaft from which all the motions are transmitted. There have been many devices for overcoming this difficulty, but probably none of them fulfill the requisite conditions so completely as that shown in Plate No. XVII. There is a striker plate on the end cradle of the traveler which causes the strut to fall into the position shown. The curved bearing bracket is hung on a pin and follows the straight arm until the driving pulley or geared wheel (as the case may be) has passed over the bracket. The other end of the striker plate then restores the bracket into its original position so that only one bearing can be down at any one time; the main shaft being, in the meantime, supported by the sleeve through which it has to pass.

The question as to the relative advantage of rope and shaft transmission is naturally very largely influenced by local circumstances. As a general rule, but one open to many exceptions, the rope system costs less and is better than the square shaft where the distance for transmitting power exceeds about 200 feet. Below that distance the shaft is probably the best, and certainly the cheapest. But machinery has often to be driven at different levels or at an angle with the point from which the motive power is transmitted. In such cases the rope possesses manifest advantages, because it can be carried by guiding pulleys in any direction required, one set of driving gear and one tightening apparatus sufficing for a great length of rope.

The steam crane referred to under system No. 7, is that known as the "steam hydraulic" system, and is worthy of mention as one of the modes in which power has been applied to portable cranes. The construction generally resembles that of the well known hydraulic crane, with multiplying chains, etc., steam taken from a boiler on the revolving platform being used instead of hydraulic pressure. It has found but little favor

with users of such machinery, and, so far as this country is concerned, it seems open to much the same objection as has been suggested with reference to the use of hydraulic power in cold weather.

The type of crane most universally employed under widely differing conditions, is that illustrated in Plates Nos. XVIII, XIX and XX, probably because machines of this type perform more functions than can be obtained from any other mechanical arrangement applied to lifting and placing loads in any desired position. All cranes of this kind should lift and turn round by steam power. That in Plate No. XIX has additional motions for altering the radius of the jib, and for traveling along the track, also capstans attached to the under carriage. These capstans are used for hauling materials so as bring them within the radius described by the jib of the crane, or for drawing up empty and shunting loaded cars, thus dispensing with the use of locomotive, horse or manual power, which, in the absence of this appliance, would be required. Machines of this type are made from 2 to 10 tons power, and they possess the advantage of each being self-contained and complete in itself, so that the number may be indefinitely increased, as and when required; they can also be distributed or concentrated to meet the exigencies of traffic for the time being.

As regards fixed cranes for loading and discharging ships, we frequently see one-third, or even one-half, of the total number of cranes, erected at a large cost at intervals along a dock or basin, entirely idle, and a considerable length of quay unoccupied, simply because certain ships have had to be berthed in such a way that the largest number of cranes can be concentrated on them. This is obviously due to the fact that when the positions of the cranes were decided, it was impossible to foresee what length of ships would be berthed opposite to them, the distance between hatchways, and so on. It would, therefore, seem that—for a given outlay—the greatest duty will be obtained from cranes which can be moved to any place where their services are required.

A very successful arrangement is where two or more railroad tracks run parallel with the water frontage, and where the cranes are of the type shown in Plate No. XXI; these discharge from the ship into the cars or to a depot beyond.

It will generally be convenient to make the gantry to span two lines of track, allowing clearance for the highest vehicle usually passing under it, the rails on which the structure travels being outside the car tracks.

By this means the quay space immediately adjoining the water, always the most valuable, and usually the most costly, is practically not trespassed upon. Cranes of this type are generally of 3, 5 or 7 tons power; for, although the bulk of the packages to be handled will be less than one ton, considerable strength is required in the revolving bed, etc., to withstand the strains incidental to a radius of 30 feet, or even more, which is often necessary for delivering the load from one point to the other without rehandling. It is obvious that if a few connections are put in between the two tracks, either may be used for loaded or empty trucks, and so facilitate removal and marshaling. It will be observed that the radius of the jib can be adjusted to reach the center of the hatchway; this, with the facility of moving along the track (both operations being performed by the driver), enables him to place the crane in such a position that the jib will clear the rigging when revolving. The capstans at the foot of the main framing are driven by the engine, and are used for hauling trucks as already described. The convenience of the driver being at a sufficient height to have a clear view of his work, notwithstanding the rise and fall of tide and variations in the height of the ship above water line as she becomes lighter, recommends this system for use under many conditions. Several modifications have been used, such as having an overhead road on which the crane travels. In some cases this has been made of wide span and the crane has traveled transversely as well as longitudinally. But the circumstances under which these motions are requisite do not often arise.

Plate No. XXII shows a mode of discharging and loading ships which may often save a considerable outlay—as it did in the case for which that design was made—for dredging and for better foundations than are required for merely carrying loaded cars. The crane is fixed at one end of a craft of sufficient beam to give the required stability when the jib is at a right angle with the length of the craft, the other end being used as a store and for sorting for different destinations.

Floating cranes of large power, such as are illustrated by Plates Nos. XXIII and XXIV, are less used than they might be, although it seems probable that a larger duty will be obtained from them than from fixed cranes of similar power. Where there is ample space for manœuvring, the arrangement shown in Plate No. XXII. answers every purpose; but for use in docks, or where space is limited, the design in Plate No. XXIII is certainly more convenient. They are made up to 60 tons power, and this might be exceeded if required.

Locomotive cranes, Plate No. XX, are made of varying powers, from 10 to 25 tons, and it will scarcely be necessary to point out how usefully they may be employed about foundries, railway repairing shops and similar works, and they are also available for use in case of accident on any part of the line. It will be seen that the motions are similar to those of the crane shown in Plate No. XIX, and it may be well to mention that light work can be done at high speeds, these being arranged to coincide, as far as possible, with the time requisite for handling. The under-carriage is always made to suit the rest of the company's rolling stock, that shown in the diagram being for a railway on the Continent of Europe.

As regards terminal freight stations, the arrangements differ so widely that no general rule can be established; but, so far as the writer's observation goes, the greatest economy in time and cost has been achieved in depots where the platforms are rather narrow, and have fixed cranes so spaced that one will reach to the center of two cars. There are similar cranes on the other side of the platform, by preference so placed that the jibs will intersect the circles described by those of the cranes on the opposite side. By this arrangement there is a better chance of separating merchandise for different destinations, and the labor incidental to separating it is proportionately reduced. Whether the cranes should be worked by hand or by power depends almost entirely on local conditions, but as the bulk of such merchandise consists of comparatively light packages, probably in most cases an inexpensive hand-power crane, such as that indicated by Plate No. XXV, will answer every purpose. These cranes command the center of the open cars, and reach to the center of the doors of box cars. The labor of "breaking down" in the latter and landing the merchandise on the platform or on a plank between the car and the platform is found to involve far less labor, and is done by cranes in less time than is occupied by trucking. But these remarks apply exclusively to depots which have been designed with a view to the use of mechanical appliances, and where the general arrangements have been made to suit them.

The duty performed by these appliances varies according to the nature of the material, but the working speed of a well-constructed crane being far in excess of the speed at which the loads can be brought within range of the jib, it is this that regulates the output, not the working speed of the crane.

As much as 80 tons per hour have been lifted a height of 20 to 30 feet, and deposited at a distance of 60 feet from where it was taken up, the loads being 1½ to 2 tons each. But men could not handle continuously at that speed, and 40 tons per hour is considered a large duty. The crane was of the type shown in Plate No. XVIII. A similar crane commonly delivers 240 barrels of oil per hour under similar conditions as to height of lift, etc. The cost of working is one driver's wages, a few hundred pounds of coal per day for each crane, some oil, wipings, etc. Five per cent. per annum is an ample allowance for depreciation.

Many illustrations of the advantage of being able to concentrate crane power might be given, but two will suffice. Three cranes of the type shown in Plate No. XXI discharged a steamer carrying 2 000 tons of hematite ore, and loaded her with 1 200 tons of wrought-iron pier-work in less than thirty-six hours. In another case two cranes, similar to that shown in Plate No. XVIII, loaded up 2 000 tons of cast-iron pipe on railway cars in less than forty hours.

The cost of this system of working, as compared with manual labor, is easily ascertained; but it would be difficult to estimate at its proper money value the larger gain arising from the increased carrying capacity obtained from a given quantity of rolling stock, or from a given tonnage of ships, and from passing a larger quantity of merchandise through the depot or dock. Evidently the same conditions apply to workshops, or any place where large quantities of materials have to be handled.

The machines referred to in this paper have been designed under the writer's immediate supervision, and have been made by his firm.

DISCUSSION.

C. E. Emery, M. Am. Soc. C. E.—This paper is a revelation in a department which has not been developed in this country as yet. The more general introduction of labor-saving machines of this character will enable us to transmit freight at a saving. One reason the crane is used in railroad work in England, is that their cars are covered with tarpaulins, which gives a very great advantage, as the cranes can be swung over the cars. On account of our system of putting everything inside box cars, we have to pay extra for the transmission of freight into and out of the cars.

ROBERT CARTWRIGHT, M. Am. Soc. C. E.—I would ask Mr. Appleby whether, as a labor-saving material, hemp is better than cotton ?

C. J. APPLEBY, M. Inst. C. E.—As to its being a better material, I hardly know in what sense you mean. Do you mean cheaper, or its capacity to do better work ? The cotton rope does very well, but a more satisfactory thing is a good hemp rope. If you use a steel rope, the cost would be greater than that of hemp for a given period.

ROBERT CARTWRIGHT, M. Am. Soc. C. E.—Then you think the hemp rope is better than the cotton?

Mr. APPLEBY.—I have not used cotton except of $\frac{5}{8}$-inch diameter. I have never used cotton rope more than $\frac{5}{8}$-inch, and I have not found it more suitable than hemp. The cotton rope costs more with us. I don't know how it may be here.

Mr. CARTWRIGHT.—It is only the best cotton rope that would do. And speaking of that, the best is the cheapest. If a cotton rope costs so much per pound, but lasts longer than the steel rope, at the end of ten years the cotton is the cheapest.

Mr. APPLEBY.—To use a metallic rope you want to have a pulley corresponding with the diameter of the rope you are using. We get a fair-sized pulley ; but where you have to deal with overhead traveling cranes you have to consider the question of head room. You can't afford to sacrifice much in the diameter of the pulleys. But the best result from a metallic rope of any kind has been with the drum.

Mr. CARTWRIGHT.—You can't drive that at very high speed.

JAMES PLATT.—Mr. Chairman, I am called on for my views by my friend, Mr. Appleby, and I must say at the outset that all my sympathies have been with the hydraulic system. Mr. Appleby's house has made a larger number and a greater variety of cranes than any other house in our little island. For many purposes I would prefer the square shaft where the length admits of it—say 300 feet. In case the rope is 5 000 or 6 000 feet, the cotton rope is best, but the diameter should be limited to $\frac{5}{8}$-inch. We have cotton ropes $\frac{7}{8}$-inch in diameter. They are doing very well. The cotton rope is undoubtedly better for high speed than hemp. Cotton is more simple. I believe that bearing pulleys of wood with iron bushes are best.

I believe, for places under cover, that the hydraulic system will be eventually tried in this country. There is still a very great scope for hydraulic cranes. I spent six months here last year and was very much

surprised to see so many workshops and depots without cranes, but no doubt you will come to it, and you have an illustration here to-night of the best plan adopted in our country. We employ steel wire rope for very many purposes. For driving cranes, etc., it does well, but unless very great care is taken of the pulley, you do a great deal of damage to the rope in a short time, and altogether it is not so good as cotton. As to hemp rope, we use ¼-inch at 600 feet.

Mr. Cartwright.—I would like to ask a question in relation to the square-shaft transmission. How long have you had it in actual use?

Mr. Appleby.—350 feet.

Mr. Cartwright.—When I speak of length, I mean the life of the shaft. How many years had you them in operation? This question will lead up to what I want to get at.

Mr. Appleby.—Well, I really don't know just at this moment, but I should think about twenty years. How long does a round shaft wear?

Mr. Cartwright.—We do not permit it to wear out; we replace it with another.

Mr. Appleby.—There is no difference between that and any other shaft, if properly proportioned. There is practically none. The great advantage of this particular system is that it doesn't matter about the length between bearings. You can have them 2 or 3 feet longer—any length you please—so that you can support your shaft to any extent you please. The life of the shaft depends upon the bearings. In this case I think you may put it down that the life of the shaft will be the same as any other transmission shaft which is properly proportioned. We have had a shaft running for forty years and it is running now.

I wish to say with reference to the question you have asked me about the life of the shaft, that I have not seen more than 350 feet of square shaft used, but that statement would probably mislead if I did not tell you that with that shaft, after very hard work, it was wonderful to see how it was twisted. Mr. Platt speaks of 300 or 400 feet as the length of the shaft. I do not agree with him, though his experience, and the intelligence he has brought to bear upon the question of hydraulic transmission, has contributed more than anything else to the success which the system merits; but I would rather put it at 200 feet, and I think the rope is cheaper and probably better for the long transmission—certainly cheaper.

Theodore Cooper, M. Am. Soc. C. E.—The only crane I know of

worked by the square shaft is at the Dickson Manufacturing Company, of Scranton, Pa. I was there recently and made an examination of that crane. Its mechanism is very excellent. They have there a square shaft 200 feet long. They can carry 25 tons from one machine-shop to the other.

I would like to ask Mr. Platt in regard to the hydraulic system. Is it not an intricate method as compared with a direct use of power? Of course I acknowledge that for certain purposes the hydraulic system is good. But for general application is it not very complicated? Steam is applied to the pumps—water is pumped to the accumulator, thence conducted to the crane. Can this system of transmitting power be the best and most economical?

Mr. Platt.—In speaking of the square shaft, perhaps I have in my mind, when I say 300 feet, where four shafts are in one piece. If a shaft is large enough to do the work it can be carried to that length, but at that length the rope is as good as the shaft. In regard to hydraulic transmission, the distinction is that you generate your power where you get a high duty of 90 per cent. In carrying that power, there is less loss in carrying high-pressure water. This is the distinction. In these cranes you have your rope running all the time, in the hydraulic system you only use the power in lifting and none in lowering. But in the power cranes you have all the time the power passing through the rope or shaft.

Mr. Cooper.—How much do you have to multiply? Don't you lose power?

Mr. Platt.—No. If we multiply three times we have a certain proportion of cylinders. If we multiply four times we get less.

W. G. Hamilton, M. Am. Soc. C. E.—What do you use in cold climates?

Mr. Platt.—We put in glycerine.

R. L. Harris, M. Am. Soc. C. E.—I might mention that there are some beautiful hydraulic cranes at the Cleveland Steel Works.

Mr. Cooper.—I think you will have to keep the water warm. Glycerine will prevent freezing, but there is sure to be leakage. My experience has been this: that with portable riveters five hours out of ten were consumed in working, and the other five in packing the joints. It is impossible to keep the hydraulic riveter constantly in motion. It is a nice piece of mechanism, but, judging by my experience I would prefer some other riveter.

Mr. APPLEBY.—The hydraulic crane is a desirable thing where it can be used without any inconvenience, and in this country it can be used, particularly in steel works. Mr. Emery, in the course of his remarks, speaks about railroads using box cars, but it is very difficult to see how they can avoid it. Our system with open tops is all very well, and works well, but we have a comparatively short distance to run. Mr. Cooper mentioned a crane which he has seen. I am glad to hear his favorable opinion of it.

Mr. HAMILTON.—You have not said anything about a walking crane, such as the Pennsylvania Railroad uses.

Mr. APPLEBY.—I have not mentioned them, because they are used very generally.

Mr. HAMILTON.—Not in this country.

Mr. APPLEBY.—They perform the same functions as a traveling crane, but are placed only where it is utterly impossible to use a traveling crane. For instance, take a line of machines with room for a single crane to run. This crane runs up the line of railroad, drops the work alongside of the machine, and takes the other work away. You could not use any other appliance in that place. Those that I am building now are driven by power, but in a great many cases a hand-driven one answers the purpose.

In the floating crane we used water to counterbalance the crane. When the crane is run into position, while they are putting the load in slings, we set a pump to work pumping into tanks, and as soon as we find that the chain is getting taut we know we have our proper weight, and stop. It is desirable to use for most of this work very large floating cranes.

GEORGE S. GREENE, JR., M. Am. Soc. C. E.—In the 40-ton floating derrick, do you move the whole float?

Mr. APPLEBY.—Yes. In some wharves I think it is better to have a propeller, because it can be used so much easier. For long distances it would be used under any circumstances, and I believe it works remarkably well.